Map Quality Assessment - Groundwork and Implementation Approach

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Abstract. Map quality refers to the overall characteristics of the map considered as a communication and reference medium for measurement and decision making. The better the quality of the map/chart the more efficient its utilization by the users community will be. In map quality assessment the problem lies with the definition and quantification of the quality characteristics of the map/chart which could lead to an overall quantified estimation. The definition of map quality may be constituted of different parameters, which either focus on the consequence of cartographic communication and thus provide a holistic description of the communication process quality or concentrate on specific parts like semiotics (for a selected purpose of map-use), structuring of semantic map content, primary model data-quality (as result of consistency of a database) or similar. Existing bibliography refers to a number of efforts addressing the issue of map/chart quality, which deal with certain elements of quality i.e. positional accuracy of the portrayed features, but not with an overall quantitative assessment of the map/chart. This paper elaborates on the issue of map quality assessment and presents part of an ongoing research on the development of a map quality evaluation methodology. The formulation of the proposed method is based on two assumptions: a. the map composition process constitutes of a series of processes/phases which are performed in digital environment b. A map is composed through the compilation of data, which undergo a number of transformations/alterations in every phase of the map composition process. Map quality assessment will result implicitly through the evaluation of cartographic data quality in each and every stage of map composition process considering that the input data satisfy minimum quality criteria. The execution of the map quality model in each phase of map composition process will facilitate the evaluation of the overall map quality.

Keywords: Map quality, Quality model, Standards

1. Introduction

Internationally and in the framework of the development of Spatial Data Infrastructures – SDIs there has been an active production and dissemination of spatial data by the pertinent authorities. Although still in an immature stage geographic organizations adopt processes for the control and certification of quality either through the use of internal specifications or through the utilization of international standards i.e. ISO spatial data quality standards 19113,19114, 19115, 19138, NATO STANAGS, INSPIRE Data Specifications etc. Relevant studies based on the national reports to ICA show that in the period 2007-2011 a number of organizations adopted spatial data quality management systems based on the ISO 9001/2008.

In spatial data production and especially in the framework of spatial data infrastructures, a constant effort in controlling data quality is in place. A typical example of this effort is the data quality model developed as a result of the ESDIN project (www.esdin.eu), which is based on the ISO 19100 series of standards and the INSPIRE specifications on data quality. On the contrary, quality assessment process in map production is limited and research results have been published on quality evaluation of the derived cartographic data mainly due to generalization. Undoubtedly there is no formal approach for the development of a quality model covering the map composition process as a whole. Along with the increase in productivity and the wider dissemination of spatial data the publication of maps and charts (in printed or digital form) is flourishing. In contrast with quality assessment of spatial data, which is based on standards, there are no international standards relevant to the quality assessment of maps/charts or official publications on this topic. This is despite the fact that throughout the years there has been an increasing concern on the identification and assessment of the error involved in map production process. Most of the existing specifications on map quality refer to their horizontal accuracy or the topology of the features portrayed (EuroGlobalMap Specifications, EuroRegionalMap Specifications, and Australian Map Horizontal Accuracy Standards etc.). It is worth mentioning the work done by a number of researchers for the assessment of change to the input data caused due to generalization (Skopeliti & Tsoulos 2001, Ruas 2001, Bard 2004, Cheng & Li 2006, Frank & Ester 2006, Mackaness & Ruas 2007, and Stoter et al. 2009). The existing bibliography lacks of an integrated model for the quality assessment in every stage of the map production process.

The issue of quality assessment of maps & charts is critical due to the fact that there is no indication on their fitness for use. Analyzing the constituents of map/chart quality we may identify them as follows:

- Geometric quality: refers to the degree of compliance of absolute or relevant positions of the features portrayed on maps/charts and their geometry with the limits set in the specifications
- Thematic quality: refers to the correctness of the categorization of the entities with respect to their attributes and the degree of compliance of the attribute values with those provided in the specifications
- Aesthetic/graphical quality: refers to the quality assessment of the map portrayal considered as the communication medium and the graphical model of the area portrayed.

From the above three components of quality only the two first (geometric and attribute quality) can be assessed and quantified (Ahonen-Rainio & Kraak 2005).

Two factors are considered important in producing a map/chart according to the relevant specifications and the users' needs:

a. The utilization of spatial data of known quality, which will have been based on internationally adopted quality standards

b. The transformations involved and the quality control of the derived data in every phase of map composition process. These transformations have a considerable influence on the map/chart data and despite the fact that the transformation results have been studied and are described in the cartographic literature there is no way to assess the quality of the map/charts produced.

Spatial data of known and acceptable quality is not by itself adequate to confer map quality. Therefore the quality level of the input spatial data cannot be considered as a quality measure of the resulting map. This is due to the transformations performed on input data in every phase of map composition process. Cartographic data quality control and assessment are the only ways to ensure that - in every phase of map composition process – input data will be transformed in a way satisfying the set specifications and will result to a product of known and acceptable quality. Assuming that the spatial data used in map composition are of acceptable quality for the intended scale and the scope of the map/chart, the effort for the quality assessment of the map/chart produced is focused on the transformations executed on the input data in the various stages of map composition. In the following section a methodology on the quality assessment of maps/charts is proposed through the control of the changes of the characteristics of map/chart data throughout the map composition process.

2. Methodology

The proposed methodology aims at the typification of the controls required for the assessment of map/chart quality and includes the design and implementation of a model that will provide quality indicators in every stage of the map composition process. The application of this methodology will result to the quantification of the quality elements associated with each map/chart.

2.1. Conceptual framework

The development of the methodology for the quality assessment of maps/charts requires:

- The structural organization of the control environment where the methodology will be applied
- The design of a quality model that will identify the tools necessary for quality assessment, the recording of the results and their synthesis for the overall assessment of quality. The term "tools" refers to the *quality elements*, their *sub-elements* and the corresponding *quality measures*. The implementation of the quality model is complemented with the adoption of quality conformance levels and the procedural evaluation of determining cartographic data quality against the set specifications.

2.1.1. Application environment

The quality control of maps/charts is considered as a process comparable with those executed in a production line according to the ISO 9001/2008 standard. An inherent element of this production line is map/chart composition divided in discrete phases and executed in a digital environment. Each phase involves certain transformations of the input data leading to the composition of the final map/chart. According to the Quality Management System of the production line, quality evaluation of the chart data resulting from each discrete phase is required ensuring the integrity of the process. Otherwise there is no sense to proceed with the next composition phase. This way input data in each phase will be transformed in the way expected and the resulting product will be of acceptable quality. It is noted here that a non-acceptable result in the process is an indication of the necessity to change the algorithm used, the values of the parameters involved etc.

The above described approach for the quality assessment of maps/charts through the quality evaluation of the result in each phase of map composition facilitates the typification of the process, which is necessary for the development of the map/chart quality model. Map/chart composition process is complex due to the number of algorithms applied, the values of the

corresponding parameters and the alternative approaches that may be followed for the same cartographic transformation. This leads to different results for chart data originating from the same database.

2.2. Logical framework

2.2.1. Identification of quality elements and their corresponding measures

For the quality assessment of the final product (map/chart) the ISO 19100 series of standards for spatial data are utilized. This choice is based on the fact that that the map/chart composition process is implemented in digital environment through the utilization and transformation of input data. In addition it is adopted that the map/chart data have the same inherent characteristics with the spatial data provided and that the cartographic data base is a by-product of the spatial data base. This family of standards - if they are properly modified and complemented - provides the framework for the quality assessment of the results of the map composition process.

2.2.2. Application of the ISO standards

Among a number of existing approaches for the application of the ISO standards the one adopted in the ESDIN program has been selected. The main characteristic of this approach is simplicity/clarity and it is implemented through the recording of the quality elements/sub-elements and their measures along with the resulting values for each data set. Quality assessment will be based on the comparison of the resulting quality values with the "conformance levels" provided in the map/chart specifications. It is pointed out that the possibility of using a numerical scale for recording the quality results is examined in order to be comprehensive by the average user. It is emphasized that the overall approach is valid under the assumption that the spatial data used in the map/chart composition process are of known and acceptable quality for the intended use.

2.3. Analytical approach

In this part the most important phases for map quality assessment are addressed:

a. Identification and analysis of the map/chart composition process (model generalization, cartographic generalization, symbolization, and toponymy)

b. Identification of the features and their attributes in the spatial data base and the map/chart database which are influenced by a specific cartographic transformation in each phase of the map composition process:

- Features
- Geometric and thematic attributes (Steiniger & Weibel 2007)
- Spatial and thematic relationships (Van Smaalen 2003)
  - Thematic relationships (Similarity and functional relationships)
  - Spatial inter-object relationships (Topological relationships: connection, inclusion, neighborhood (Yaolin et al. 2007) and geometric relationships: comparison with respect to feature geometry)

At this stage a decision must be taken on the level of application of quality elements i.e. whether it will be at the entity level or the dataset level. This depends amongst others on the nature of the transformation applied: projection transformations influence the whole dataset whereas generalization may have local influence changing the characteristics of an entity.

c. Identification of the quality elements and sub-elements. The quality elements and sub-elements of the features, their attributes and the associated relationships influenced by cartographic transformations in each phase in the map composition process are identified according to ISO 19113. It is evident that different quality elements are involved in each transformation. On the other hand and for the integrity of the quality model it is necessary to identify and measure at least one quality element in each phase. The idea here is the correlation of the various transformations with the quality elements of the standard in order to relate quality assessment with the result of each transformation.

d. Identification of the conformance levels. Map/chart specifications refer to the conformance levels pertaining to each feature, attribute and transformation. It is realized though that map/chart specifications are not complete and missing values should be identified for each quality element involved in the process. It is noted though that in the framework of the development of the map/char quality model the effort is focused mostly on the proper selection of quality elements and their measures and not on the identification of the conformance levels.

e. Assessment of the results. This stage refers to the measured change of quality with respect to the conformance levels adopted in each phase of the composition process. A considerable difference with the assessment of spatial data quality is that the checks involved refer to the full data set and not to certain samples. At first glance such an approach may seem awkward but it is considered necessary for a reliable overall result.

3. Application on model generalization

Model generalization is the first step in the map/chart composition process in digital environment and the first attempt for the development of the quality model refers to this stage. For this application the EuroBoundary data base is used and generalized for the production of the model EuroGlobal map database. Due to the extent of the complete quality model its presentation will be restricted to the Lake areas feature class (LAKERESA - BH080) dataset. The choice of the particular dataset is due to the fact that the EuroGlobal map specifications are considered adequate and have been tested for years by a number of European mapping agencies. The approach followed is based on the definitions for model generalization provided by Regnaut and McMaster (2007) and the correlation of the selected quality elements of the ISO 19113 with the corresponding operations of model generalization. According to Regnault and McMaster (2007) in the framework of model generalization the following transformations may be expected: a. Generalization of the data schema, b. Change in data categorization and c. Modification of the relevant attributes. Model generalization is considered as a synthesis of information abstraction (Nyerges 1991) and it is implemented on: a. the schema level aiming to the transformation of the structure of the initial schema and b: the instance level aiming to the transformation of the elements in order to be compatible with the resulting data base. Quality checks refer to features, their attributes and their relationships.

3.1. Euro Global Map Data Quality Model *Process:* Model Generalization

Structural elements of the model:

3.1.1. Map Specifications

According to Eurogeographics Specifications (2008) the structural elements of the model are:

a. EGM Conceptual model, describes the way data are organized in feature classes in the geo-database, defines feature types, includes feature definitions, attribute definitions, topological and other relationships descriptions.

b. EGM Logical model is based on DIGEST vector data model which adheres to the geo-relational data model. Feature geometric primitives are Isolated or Connected Nodes, Edges, Faces and the acceptable level of topology is planar graph (level 2) or full topology (level 3).

c. Rules for collecting information: The main selection criteria for features are the portrayal criteria (e.g. ‘Portrayal criteria: Lakes larger than 0.5 km^2).

d. Rules for filtering information:

- Fuzzy tolerance: 5 meters (topology rule based on specifications).

- Model generalization rules depend on map scale, e.g. minimum distance between two items considered as contiguous: 250 m.

3.1.2. Map Quality Requirements:

They are based on feature definitions and rules for collecting and filtering information described in map specifications, e.g. 'QR1 (Selection criteria): All lake areas larger than 0.5 km^2 are included in the dataset'.

Quality requirement parameters:

a. Quality scope: implementation field, e.g. 'All items classified as lake areas in the data set'.

b. Applicable Quality elements (ISO 19113), e.g. 'Completeness/ Commission'.

c. Data Quality Measure (ISO 19138), e.g. 'Íd 2 (error count/number of excess item)'.

d. Data Quality Evaluation Method, e.g. 'Internal check: Count the number of items with Shape Area < 0.5 Km^2'.

e. Data Quality Conformance Level, e.g. 'Zero violations in dataset'.

3.1.3. Map Composition Process - Phases

a. Analysis and typification of map composition phases, e.g. 'Process: model generalization/Operations: Modification of the class intension, object elimination (because of the 'modification of the class intension' operation), object aggregation/ merging'.

b. Determination of map elements and characteristics affected by the operations in every phase of map composition process, e.g. model generalization operations: 'modification of the class intension affects the entities, 'object elimination affects the entities and the topological relationships, object aggregation/merging affects the attributes'.

3.1.4. Additional elements of map composition process:

Software used ArcGis ver. 10.1.

3.1.5. Map quality control, includes two stages:

a. Determination of the applicable quality elements (ISO 19113) affected by the operations in every phase of map composition process, e.g. model generalization operations: 'modification of the class intension affects the quali-

ty element/sub element of completeness/commission, 'object elimination affects the quality element/sub-element of logical consistency/ topological consistency, object aggregation/ merging affects the quality element/sub-element of thematic accuracy/ non-quantitative attribute correctness'.

b. Quantification of quality variation and aggregation of data quality results

Feature type/ Attribute	**Quality Element/ Sub element**	**Quality Measure**	**Description**
LAKERESA (BH080)	Completeness/ Commission	Error count /id 2	*Scope*: All items classified as "LAKERESA" in the dataset.
Feature Definition: A body of water surrounded by land		Number of excess items (Full inspection)	*Measure*: All lake areas larger than 0.5 km2.
			Measure definition: Number of excess items in the dataset in relation to the number of items that should have been present.
			Evaluation method description: Count the number of items with Shape_Area < 0.5 Km2.
			Evaluation method type: Internal
			Result value type: Integer
			Result unit: Number
			Conformance level: Zero commissions in dataset

Table 1. Quality element, measure and conformance level for feature LAKERESA

3.1.6. Knowledge management:

- Implementation of the minimum required quality controls
- Possible redefinition of conformance levels
- Repetition of each phase of map composition process to obtain results compliant to map specifications, excluding algorithms that affect in an inappropriate way the entire process
- Identification of the relation between the parameters of each transformation and the quality variation
- Determination of the degree of the transformations impact on map features and characteristics

4. Results

The results of model generalization of the hydrographic network are portrayed in figures 2 and 3. Figures 1 and 2 portray the hydrographic network in its original form and after model generalization at the 250.000 scale. Figure 3 portrays the result of model generalization at the EGM scale 1:1.000.000. These figures show that the application of the quality model described are realistic and that the resulting cartographic database can be utilized undoubtedly as an input to subsequent stages of map composition. For these stages another model for quality assessment will be developed.

5. Conclusions

An approach to the assessment of map/chart quality is considered feasible. This can be considered as a step towards cartographic process integration. A common quality model can be defined which can be used by map producers. Such a model will lead to a quantified overall assessment of map/chart quality. The authors believe that a trusty indication of quality on the maps produced will contribute to the standardization of the map composition process and the improvement of the reliability of cartographic products. It will also enable map users to look for those maps that fulfil their needs for the applications they are involved in.

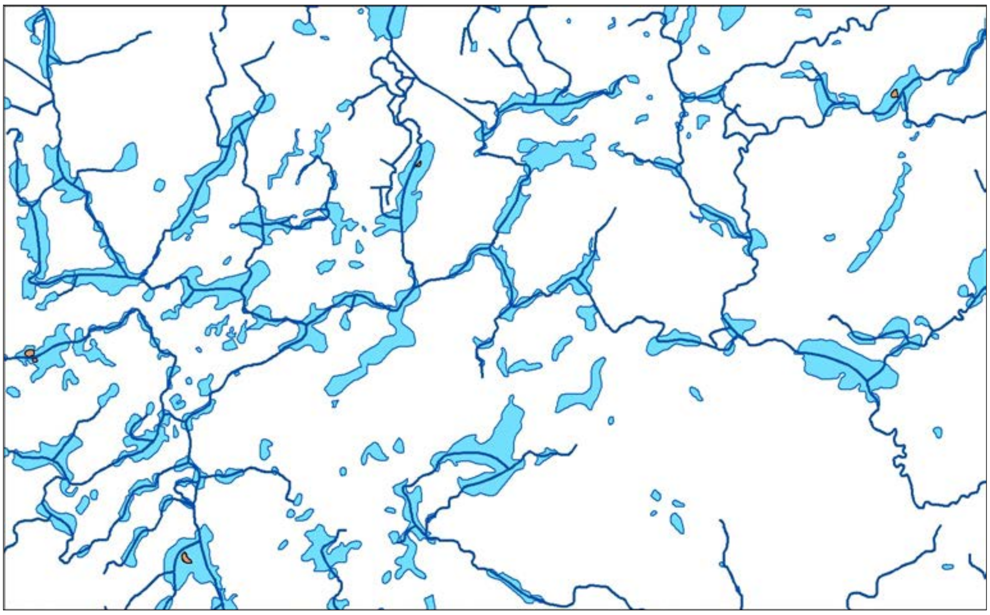

Figure 1. EuroRegional Map – Hydrographic network (original data), scale 1:250.00

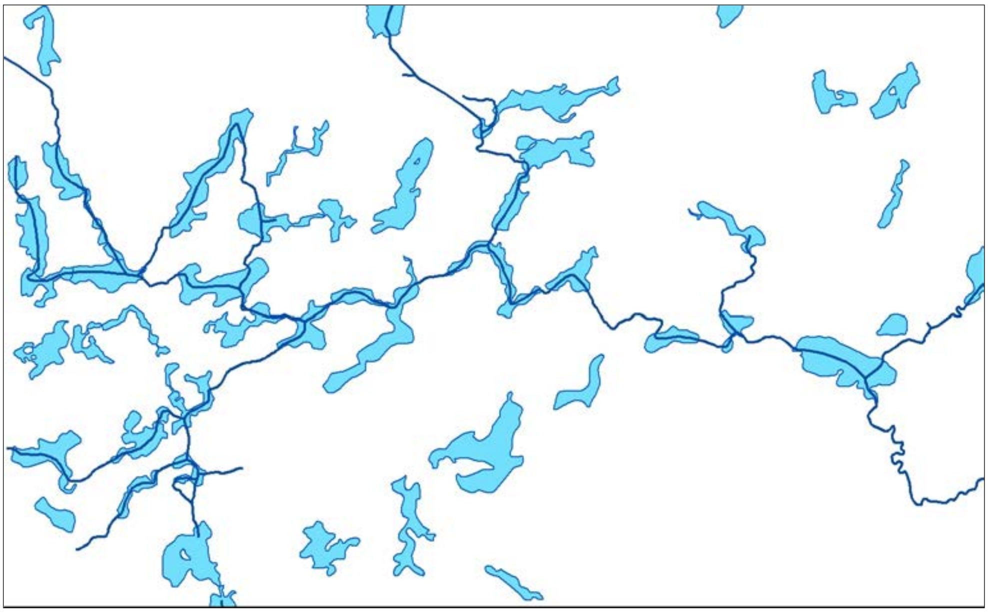

Figure 2. EuroRegional Map – Hydrographic network after model generalization, scale 1:250.000

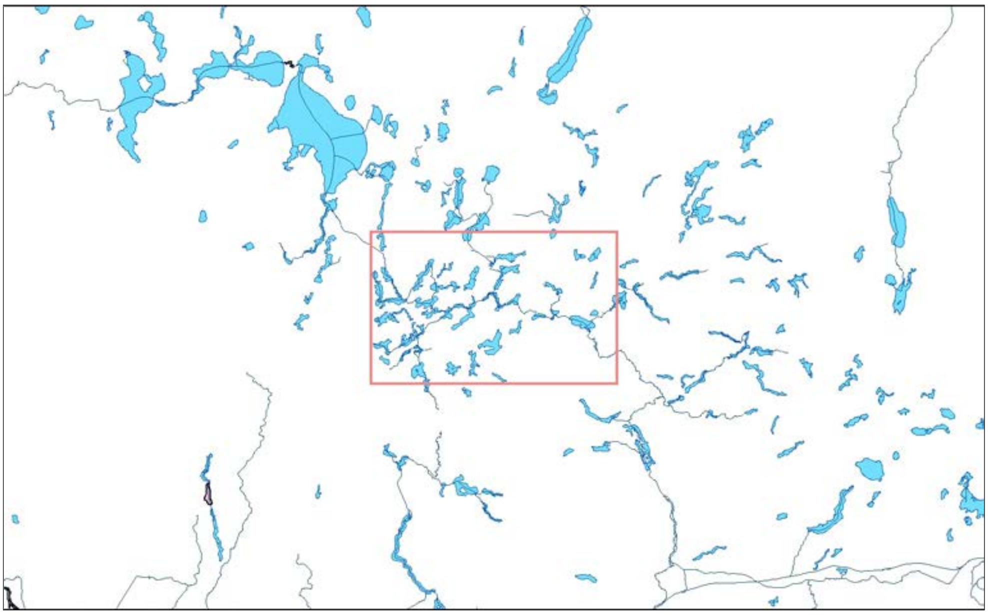

Figure 3. EuroRegional Map – Hydrographic network after model generalization, scale 1:1.000.000

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